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The need of harmonization: from building product information to the whole process of the construction

Beatriz Rivela — *Department of Construction and Technology in Architecture, Technical University of Madrid, Spain* — b.rivela@abio-upm.org

Cesar Bedoya — *Department of Construction and Technology in Architecture, Technical University of Madrid, Spain* — cesar.bedoya@upm.es

Alfonso García-Santos — *Department of Construction and Technology in Architecture, Technical University of Madrid, Spain*

LCA has been traditionally concerned with product design, but by limiting the functional unit of an LCA to a building material or component, a number of functions that should be provided by buildings cannot be properly taken into account. Nowadays there is an intensive standardization process on building environmental assessment and CEN/TC 350 is doing a remarkable job by providing a reference framework and developing voluntary horizontal standardized methods for the assessment of the environmental performance on both new and existing buildings. The objective of the present work is to assess the importance of harmonization in the field of building environmental assessment. More than 80 case studies have been reviewed in order to describe and classify the results of the LCA studies regarding their goal and scope and their practical methodology implications, by discussing the variability associated to main hypotheses such as the functional equivalent selected and the choice of impact categories.

Introduction

Sustainable development in construction sector

Sustainable development requires methods and tools to measure and compare the environmental impacts of human activities. Providing society with goods and services contributes to a wide range of environmental impacts (Sharma et al., 2011). In this sense, the construction sector is of strategic importance for the economy, social well-being, energy & climate change and environment protection.

It can be stated that the current situation of the European residential buildings stock in terms of environmental performance is far from the currently discussed low-energy standards and there lies a tremendous potential for improvements (Nemry et al., 2008).

More than ever, the application of LCA is fundamental to sustainability and improvement in building and construction. LCA is recognized as an innovative methodology which improves sustainability in the construction industry throughout all stages of the building life cycle.

The standardization process towards sustainable construction

Nowadays there is a wide range of initiatives and instruments for sustainable construction, innovation, rethinking the value chain and international competition. However, initiatives pursue different objectives; there are large disparities between countries and still significant room for improvements.

The construction sector is the biggest single area of work in CEN with +/- 3000 work items, both product standards and test methods. Considering the requirements of the Construction Products Regulation (CPR), a number of harmonized product standards will need amendments to allow for the establishment of DoP (Declaration of Performance) as from the 1st July 2013 (CEN, 2011).

The sustainability assessment quantifies impacts and aspects to assess the environmental, social and economic performance of buildings using quantitative and qualitative indicators, both of which are measured without value judgments. In carrying out assessments, scenarios and a functional equivalent are determined at the building level. Assessment at the building level means that the descriptive model of the building with the major technical and functional requirements has been defined in the client's brief or in the regulations, as illustrated in Figure 1 (EN 15643-1:2010).

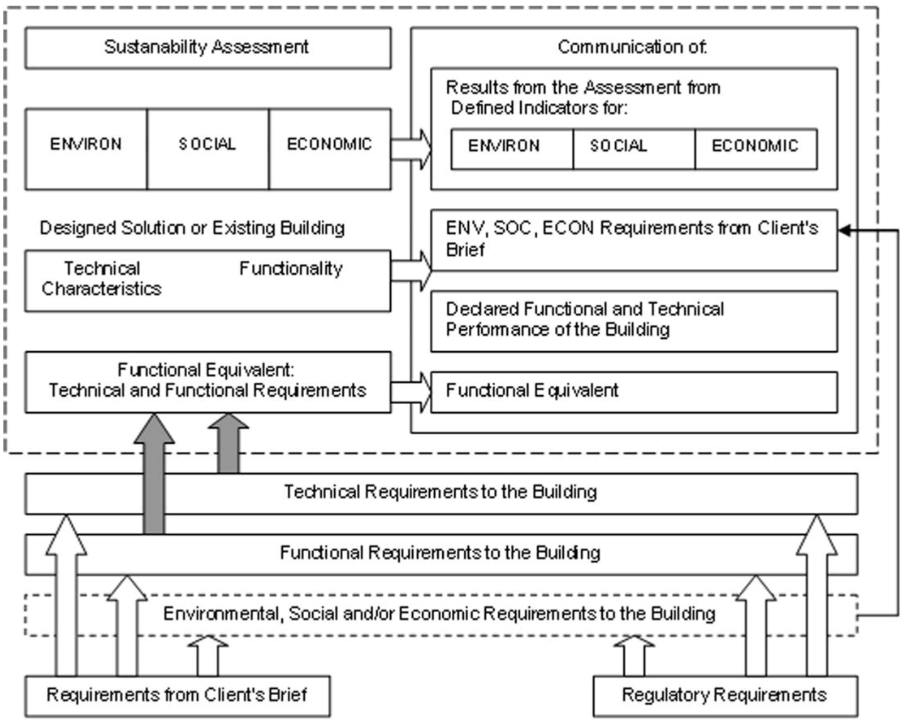

Figure 1. The concept of sustainability assessment of buildings (EN 15643-1:2010)

Assessments can be undertaken for the whole building, for parts of the building which can be used separately or for elements of the building. By reference to the functional equivalent the results of assessments can be presented in a systematic way. The functional equivalency forms the basis for comparison at the building level. In concept, the integrated building performance incorporates environmental, social and economic performance as well the technical and functional performance, and these are intrinsically related to each other, as illustrated in Figure 2 (EN 15643-1:2010).

Framework for the assessment of environmental performance

The work of CEN/TC 350 "Sustainability of construction works" will be used when mandates to cover the Basic Requirements for Construction Works (BRW) will be issued. Development of CEN/TC350 standards has taken into account the needs of the relevant EU policies related to the construction products relying on the performance based approach & the level of works. Manufacturers are request to give environmental information in a form of Environmental Product Declaration (EPD) according to the unified European method by CEN/TC350 (EN 15804:2012). CEN/TC350 provides the European standardized basket of indicators for sustainable construction. From the regulatory point of view, the indicators defined in CEN/TC350 standards (e.g. in EN 15978:2011 and EN 15804:2012) should be regarded as the basket of environmental indicators that have an existing European unified method.

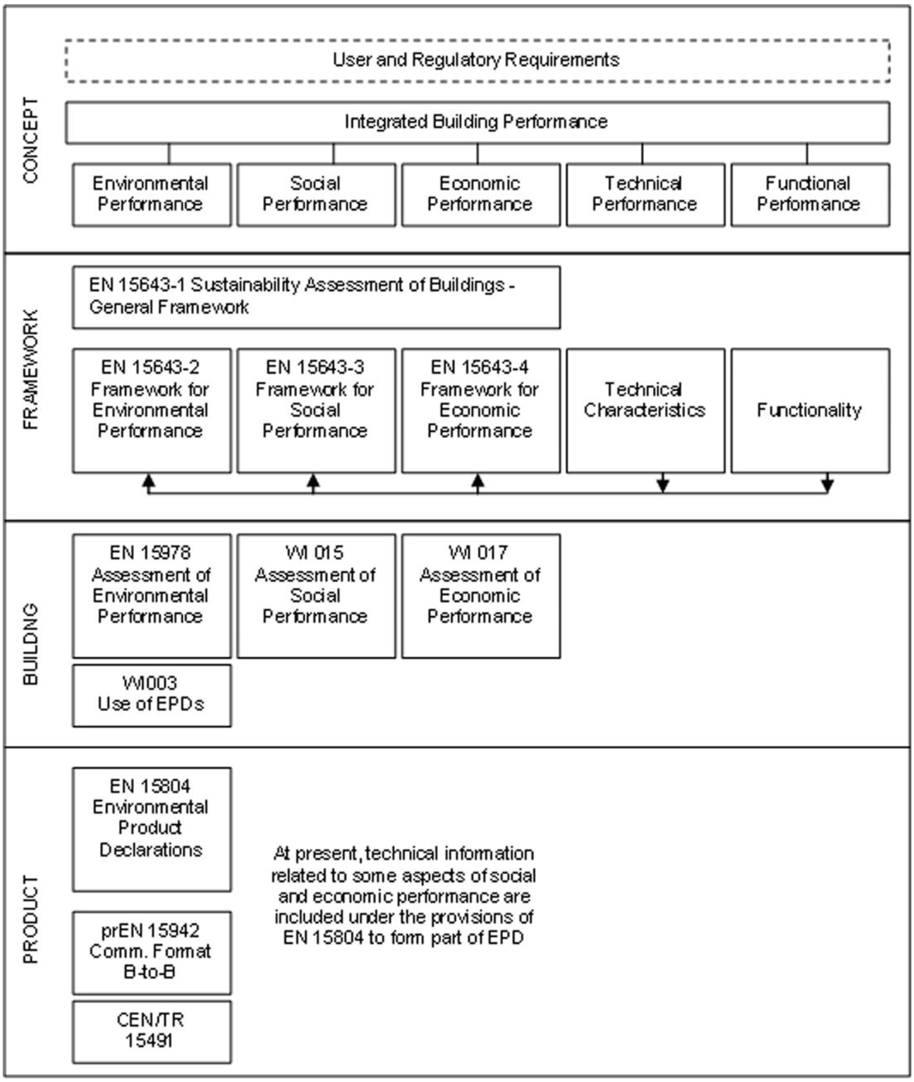

Figure 2. The work programme of CEN/TC 350 (EN 15643-1:2010)

The purpose of the European Standard EN 15643-2:2011 is to provide a framework with principles, requirements and guidelines for the assessment environmental performance of buildings. In the drafting of this European standard, ISO 21930 and ISO 21931-1 have been taken into consideration (EN 15643-2:2011).

Environmental product characteristics derived from BWR3 and BWR7 should become "essential product characteristics" and part of Declaration of Performance as soon as any Member State or the European Commission (e.g. caused by other directives) have requirements to declare the defined environmental indicators or they set actual limit values to the buildings on the life cycle basis, or on the products in its intended use (as part of the works) e.g. for:

- Emissions of greenhouse gases as part of BWR3,
- Materials for recycling after demolition as part of BWR7 or;
- Use environmentally compatible raw and secondary materials as part of BWR7

Impacts and aspects shall be assigned to the information modules of the building life cycle in which they occur, as it is described in Figure 3.

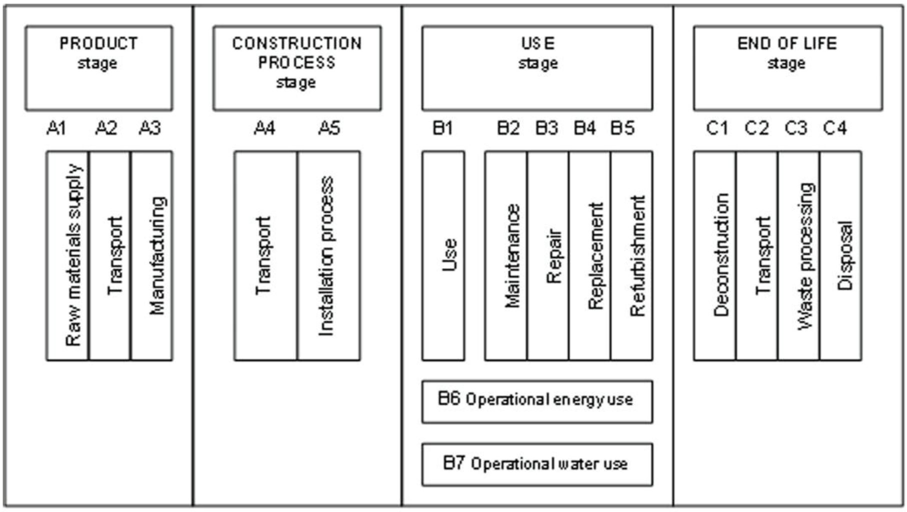

Figure 3. The building life cycle information modules applied in the assessment of environmental performance of a building.

Within this environmental framework the building life cycle starts with the acquisition of raw materials. It proceeds through the manufacture of products, construction work processes, actual use including maintenance, refurbishment and operation of the building, and finally at the end of life, deconstruction or demolition, waste processing in preparation for reuse, recycling and energy recovery and other recovery operations, and disposal of construction materials. Information from these activities is needed to assess the environmental impacts and aspects of the building (EN 15643-2:2011).

A building assessment requires information on the environmental impacts and aspects for all information modules A to C. The environmental impacts and aspects beyond the building life cycle shall be represented by information module D (additional module not showed in Figure 3). This supplementary information module D is optional.

It is remarkable that the environmental performance of a building is only one aspect of its sustainability. The social and economic performances of the building (described in the framework standards EN 15643-3:2012 and EN 15643-4:2012) are also aspects of sustainability that should be assessed as part of a sustainability assessment. The evaluation of technical and functional performance is beyond the scope of the standard; technical and functional characteristics are taken into account by reference to the functional equivalent, which also forms a basis for comparison of the results of assessments.

To provide calculation rules for the assessment of the environmental performance of new and existing buildings is the purpose of the European standard EN 15978:2011. The standard gives the description of the object of assessment; the system boundary that applies at the building level; the procedure to be used for the inventory analysis; the list of indicators and procedures for the calculations of these indicators; the requirements for presentation of the results in reporting and communication; and the requirements for the data necessary for the calculation. The object of assessment is the building, including its foundations and external works within the curtilage of the building's site, over its life cycle; the assessment can be also restricted to a part of a building or to an assembled system (part of works). Comparisons between the results of assessments of buildings or assembled systems shall be made only on the basis of their functional equivalency (EN 15978:2011).

Bearing in mind the ongoing standardization process and the future requirements that will be promoted within the European context, the purpose of the present work is to analyse the current scenario of the environmental building assessment practices as a basis to highlight the importance of harmonization in this field.

Methodology

In a first step, more than 80 case study publications corresponding to the period 2001-2011 were systematically reviewed in order to describe and classify the results of LCA studies in terms of goal and scope and practical methodology implications. It was observed that several studies were focused on building materials and components.

Publications related to LCA of the whole process of the construction were selected for a further analysis, following a multicriteria perspective of transparency, accessibility and geographic diversity. The selected case study publications are shown in Table 2.

For the purpose of this work, buildings are categorised according to their usage. Residential buildings are defined as buildings primarily constructed for residential occupancy. The classification for residential buildings was defined according to IMPRO-Building Project (Nemry et al., 2008):

- Single-family houses: Single-family houses include individual houses that are inhabited by one or two families. Also terraced houses are assigned to this group.
- Multi-family houses: contain more than two dwellings in the house.
- High-rise buildings were defined as buildings that are higher than 8 storeys.

Non residential buildings are those which are used for commercial purposes. Commercial buildings studied were classified into offices and hotels.

Table 1. Selected case study publications

Building use / Country	Reference
Residential buildings	
UK	Yohanis and Norton, 2002
Several	Kotaji et al., 2003
USA	Scheuer et al., 2003
Switzerland	Matasci, 2006
Several	Sartori and Hestnes, 2007
Scotland	Asif et al., 2007
Japan	Gerilla et al., 2007
Greece	Koroneos and Kottas, 2007
Belgium	De Meester et al., 2009
India	Shukla et al., 2009
Spain	Ortiz et al., 2009
Spain-Colombia	Ortiz et al., 2010a,b
Sweden	Gustavsson and Joelsson, 2010
Sweden	Gustavsson et al., 2010
Italy	Blengini and Di Carlo, 2010
Italy	Aste et al., 2010
Several	Sharma et al., 2011
Commercial buildings	
Office	
Finland/USA	Junnila, 2004
Thailand	Kofoworola and Gheewala, 2008
China	Xing et al., 2008
Hotel	
Spain	Rosselló-Batle et al., 2010

The degree of methodological consistency of research with the future European standard in the field of building environmental assessment has been analysed in depth. The variability associated to main hypothesis such as the equivalent functional selected and the choice of impact categories was examined in relation to EN 15643-1:2010 and EN 15978:2011 standards as follows:

Functional equivalent

According to EN 15643-1:2010, the functional equivalent of a building or an assembled system (part of works) shall include but is not limited to information on the following aspects:

- Building type (e.g. office, factory, etc.);
- Pattern of use (e.g. occupancy);
- Relevant technical and functional requirements (e.g. regulatory framework and client's specific requirements);
- Required service life.

The standard states that "Other specific requirements and exposure to climate and to other conditions from the immediate surroundings may be relevant for inclusion in the information on the functional equivalent".

Environmental indicators

Predetermined indicators that shall be included in the assessment are summarized in Table 2. The environmental indicators used in the EN 15978:2011 standard represent the quantified environmental impacts and aspects caused by the object of assessment during its whole life cycle. Indicators have been chosen on the basis that there are agreed calculation methods for the indicators referred to in this European Standard. Other indicators, for which there is no scientifically agreed calculation method within the context of LCA - e.g. human toxicity, eco-toxicity, biodiversity, land use - are not included.

Table 2. Indicators describing environmental impacts. Source: EN 15978:2011.

Indicator	Unit
Global warming potential (GWP)	kg CO_2 equiv
Depletion potential of the stratospheric ozone layer (ODP)	kg CFC 11 equiv
Acidification potential of land and water (AP)	kg SO^{2-} equiv
Eutrophication potential (EP)	kg $(PO4)^{3-}$ equiv
Formation potential of tropospheric ozone photochemical oxidants (POCP)	kg Ethene equiv
Abiotic resource depletion potential for elements (ADP_elements)	kg Sb equiv
Abiotic resource depletion potential of fossil fuels (ADP_fossil fuels)	MJ, net calorific value

Following these two main methodological aspects, the discussion of the degree of consistency of research with the future European standard is presented. Finally, the need for a harmonization process is outlined, identifying major obstacles and opportunities.

Results and discussion

The study of building characteristics in different geographical contexts shows the high degree of diversity in specificity construction techniques and architectural style. We build differently because of climatic conditions, geology, different safety levels, uses and traditions. The variation in each design can affect the environment during all life cycle stages of a building.

Regarding the functional equivalent description, it is observed that pattern of use (e.g. occupancy) and relevant technical and functional requirements (e.g. regulatory framework and client's specific requirements) are not adequately described in most of the case study analyzed. With the exception of the work presented in Ortiz et al. (2009) and Aste et al. (2010), the description of the scope of the studies does not meet the requirements of European standards to ensure comparability of results. The most common required service life established is 50 years in most of the case studies, but it also varies, reaching 100 years in Gustavsson et al. (2010).

It should be noted that there is no specific mention of occupancy or use patterns, factor highly relevant in relation to the environmental impacts associated to the use phase of the building. As a general rule, the results of the studies indicate that when building is used for the purpose for which it is constructed, the maximum energy consumption is during the use phase.

With respect to the environmental categories under study, the review has demonstrated that most LCA studies focus on energy consumption. Although studies have been focused on energy use and greenhouse gas emissions (GHC), the concept of CO_2 equivalent emissions has not been correctly introduced in many cases, restricting the analysis to CO_2 emissions as the only element considered (excluding, the remaining GHC).

The results of IMPRO-Building project showed the similarity of trends over the different impact categories when the different building types according to zones are compared. This reflects the important role of energy use in most of the environmental impacts quantified, first as a result of fuel combustion for space heating, and, second, as a result of the industry processes involved in the manufacturing of building products. Consequently, the conclusions of the project recommend both primary energy use and greenhouse gas (GHG) emissions as good proxy indicators to assess the environmental performance of the buildings (Nemry et al., 2008). Moreover, environmental burdens of global warming potential (GWP) have received special attention in the international political arena, and become a priority for improvement actions in the European context. These two factors, coupled with the increased availability of data to quantify GHG, justify the fact that GWP has been the indicator most commonly analyzed in the literature.

Nevertheless, although they have received much less attention, some studies show the results of other environmental impacts. Six of the case studies analyzed present data related to acidification potential of land and water (AP). The environmental impact categories of depletion potential of the stratospheric ozone layer (ODP), eutrophication potential (EP), abiotic resource depletion potential for elements (ADP_elements) are found in only three of the works under study. The formation potential of tropospheric ozone photochemical oxidants (POCP) is just included in one case study.

The results of this review show the lack of consistency of research works with the future European standard and also illustrate the need for improving the harmonization of existing instruments based on life cycle approach for the assessment of the sustainability performances. Comparisons between the results of assessments of buildings or assembled systems (part of works) – at design stage or whenever the results are used – shall only be made on the basis of their functional equivalency. This requires that the major functional requirements shall be described together with intended use, and the relevant specific technical requirements. This description allows the functional equivalency of different options and building types to be determined and forms the basis for transparent and reasonable comparison (EN 15643-1:2010).

Remarkably, the building climate context is a determining factor on which guidelines of classification should be established in order to analyze the environmental performance. In recent work, there is a wide variation in energy consumption during the use phase of the building from 18.7 to 150 KWh/m^{2}year. The valuation of the environmental of performance of the building can not be done in isolation without regard to specific geographical context. In this sense, it should be noted that the standards developed under CEN 350 framework do not set the rules for how different building assessment schemes may provide valuation methods; nor do they prescribe levels, classes or benchmarks for measuring performance. Providing guidelines and normalization factors that allow the identification of the relevance of the environmental impacts calculated in the assessment is a priority task to be performed by the scientific community towards a tangible reduction in overall environmental impact.

Final remarks and future outlook

LCA has been traditionally concerned with product design, but by limiting the functional unit of an LCA to a building material or component, a number of functions that should be provided by buildings, such as thermal conditioning, cannot be properly taken into account: decisions based on isolated LCA for materials or components might lead to erroneous conclusions. Maybe because of the complexity of the life cycle of a building, researchers in the past often opted for building materials, building products or building components as subject for LCA research. However, recently, research has been executed on the application and adaptation of the LCA framework to buildings as a whole.

The present review, though not claiming to be exhaustive, reveals the progressive evolution of LCA in the building sector during the last years. In order to contribute to a more sustainable construction it is necessary to improve the coherence, consistency and completeness of construction standards. The Commission and CEN need to seek joined-up thinking in the field of sustainability and ensure the recognition of existing standards as far as possible. Guidance should be developed by the CEN Construction Sector Network, in conjunction with CEN/TC 350, to ensure consistency between product standards and the standards for assessment of sustainable construction. In addition, the development of Building Information Modelling (BIM) should be encouraged.

The participation of all stakeholders directly concerned by the development of a standard should be promoted as a priority. Getting stakeholders involved can be accomplished by making standardization activities known, reducing thresholds, provide explanation regarding the standardization system and developing consistent data sources and metrics on "green" buildings valuation via creation of calculation software.

Adapting "real life" to the new normative environment is a challenge we are facing nowadays. By systematically directing environmental issues towards standardization, the environmental impacts of products and services could therefore be reduced. To promote an environmentally friendly construction it is necessary to define properly the basis for comparison at the building stage: to establish appropriate functional equivalent scenarios considering that the climatic area conditions relevant impacts (i.e. the ones generated by energetic consumption for conditioning purposes during the use phase) and to enforce coherent practical methodology issues.

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